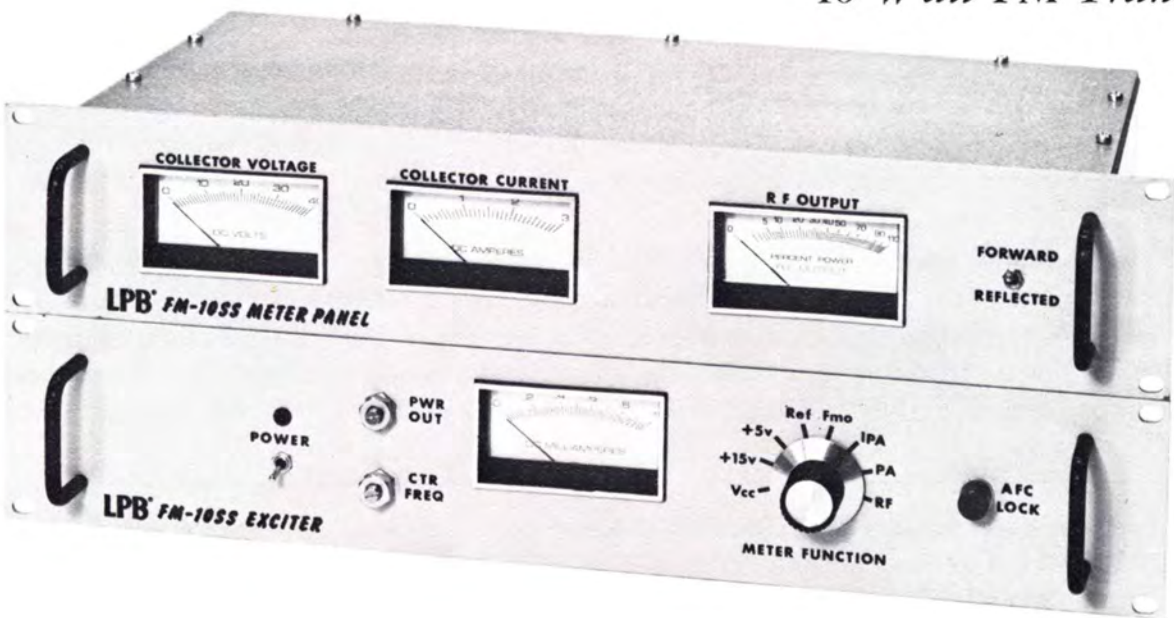
LPB®

Educational FM Transmission Equipment

Model FM-10SS
10 Watt FM Transmitter



Burden Associates
20944 Sherman Way, Suite 216
Canoga Park, Calif. 91303
(213) 340-4590

The LPB Model FM-10SS . . .

- State-of-the-art 100% solid state circuit design
- Exceeds F.C.C. requirements for all categories of FM broadcasting
- Power output adjustable from 5 to 20 watts
- Output unconditionally stable and protected against all mismatches
- Unusually complete operational monitoring with 4 meters
- On-carrier direct FM modulation for reliability
- Phase locked loop frequency synthesizer for ultimate frequency stability
- Only +8 dBm audio input level required for full modulation

LPB® *Model FM-10SS Transmitter Features*

The LPB FM-10SS 10 watt FM Transmitter exceeds F.C.C. requirements for all categories of FM broadcast operation. It is Type Accepted for educational, commercial, mono, stereo and SCA operations. Over 300 are now in service and have received repeated acclaim from broadcast engineers for their superiority to much higher priced equipment.

Performance and Reliability: The latest state-of-the-art solid state circuit techniques are used in the FM-10SS for optimum performance combined with foolproof operation. Center frequency is generated in a phase locked loop based upon an 8 mHz reference crystal. The output frequency of the transmitter is digitally synthesized from the count-down programming of the loop. This eliminates a different crystal requirement for each FM broadcast channel, and even allows easy field change of frequency if needed. The resulting frequency stability is guaranteed at least four times in excess of F.C.C. broadcast requirements!

Rugged Power Amplifier Stage: The power amplifier and associated circuits are unconditionally stable and capable of withstanding any phase or magnitude of output VSWR indefinitely without damage. This means that any incorrect connection or accidental disconnect or shorting of the FM-10SS output is immediately followed by full recovery to full-specification operation with no circuit damage. This is but one example of the foolproof operation of the FM-10SS, a truly important feature for Class D educational broadcasters with limited technical staff.

Low Audio Input Level Requirement: The FM-10SS will operate directly from the conventional +8 dBm (0 VU) output level of a broadcast audio console. Other FM transmitters require a minimum of +10 dBm audio input for 100% modulation, hence they require the addition of some form of audio amplifier at the transmitter location.

Complete Metering: Unusually complete metering is another advantage of the LPB FM-10SS Transmitter. A meter on the Exciter panel may be switched to monitor eight different circuit functions, while three additional meters on the Meter Panel present full-time monitoring of collector voltage, collector current and RF output power. For 10-watt Class D operation, the RF output power meter is factory calibrated for 10 watts power at 100 percent indication on the meter.

Mounting Flexibility: The FM-10SS consists of two 3½ inch relay rack panels with interconnection cables. These may be mounted in a relay rack in the station or near the antenna, as the individual situation requires. The highly efficient circuitry consumes only 50 watts of AC input power.

Companion Stereo and SCA Generators: For stereo operation, the inexpensive model 772 Stereo Generator is available from LPB. The FM-10SS also interfaces directly with the Optimod compressor/limiter/stereo generator without the addition of expensive interface units required for many FM transmitters. The model 811 SCA Generator is also available for use with the FM-10SS.

The FM-10SS for Exciter Service: The FM-10SS Exciter panel will frequently be found in service at high power commercial and educational broadcast stations as the exciter for the main transmitter. Especially where older tube-type transmitters are in operation, substantial system performance upgrading may be obtained at very low cost by the replacement of older types of exciters with the FM-10SS.

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Model FM-10SS Transmitter Specifications

Frequency Range . . . 88 mHz to 108 mHz (Programmable)
Power Output. . . .Adjustable 5-20 watts, 10 watts nominal
Type of Emission . . . . 180F3 or 300F9
Modulation Capability . . . . 150 kHz Peak Deviation @ 1% THD maximum
Frequency Stability . . . . ±500 Hz (−10°C to +55°C)
Output Impedance. . . . . . . 50 ohms, type N Jack (female)
VSWR Protection . . . . .any magnitude or phase
Harmonic & Spurious Suppression . . . . .better than 80 dB
Audio Frequency Response. . . . . . ±1 dB (50 Hz - 15 kHz, 75 µsec pre-emphasis)
Audio Distortion. . . .0.35% max. THD @ 75 kHz deviation
FM Noise. . . . better than −70 dB (Below 75 kHz deviation with 75 µsec de-emphasis)
AM Noise. . . . . .better than −55 dB
Stereo Separation . better than 40 dB from 30 Hz - 15 kHz with Model 772 Stereo Generator
Crosstalk (main to SCA) . . . .−55 dB

Crosstalk (SCA to main) . . . .−65 dB

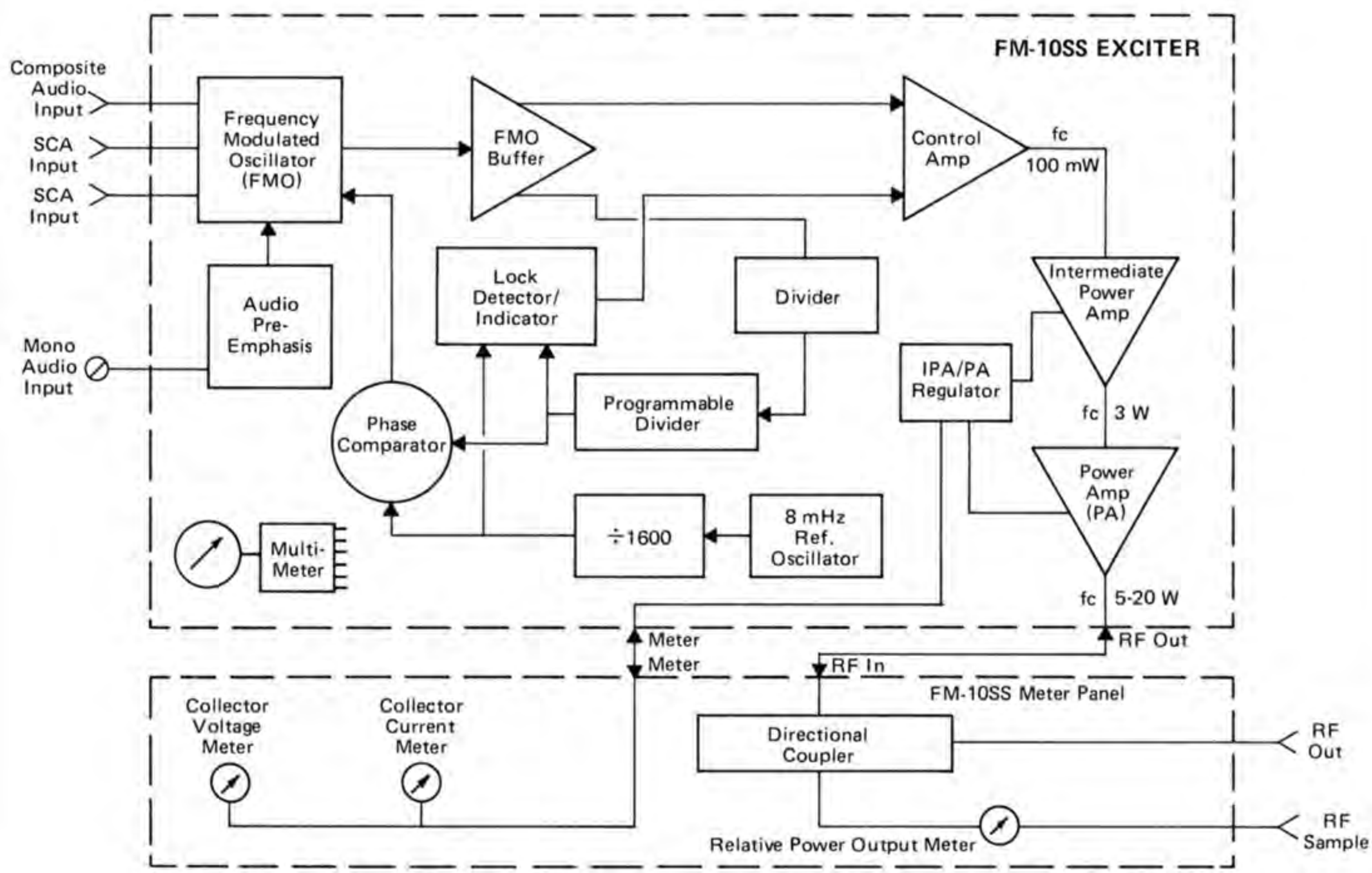
Mono Input
- Impedance . . . . 600 ohms balanced, barrier strip screw connection
- Level. .+8 dBm for 100% modulation (75 kHz deviation)
- Pre-emphasis. . . . . 75 µsec (50 µsec optional)

Stereo Input
- Impedance . . . . . . .10 K ohms, BNC Female Connector
- Level. . .4 Vpp for 100% modulation (75 kHz deviation)

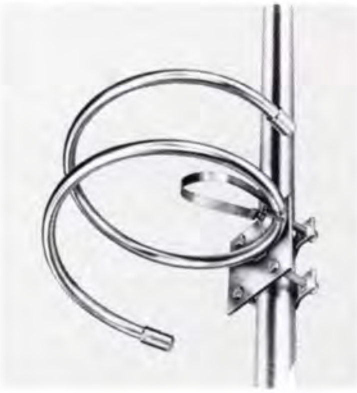
SCA Inputs (2)
- Impedance . . . . . . .10 K ohms, BNC Female Connector
- Level. . . . . 1 Vpp for 10% injection

Dimensions:
- Exciter . . . . 3½" H x 19" W x 14" D
- Meter Panel . . . . 3½" H x 19" W x 8" D

Maximum Operating Temp. . . . . . .131°F (55°C) Ambient

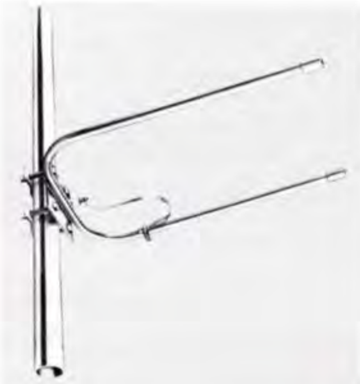


Phelps Dodge *Antennas*



CIRCULARLY POLARIZED FM EDUCATIONAL ANTENNA SPECIFICATIONS

Type No. And Bays	Power Gain	Gain In db	Field Gain	FS @ 1 Mile 1 KW, MV/M	Net Wt. Lbs.	Power Rating KW	Wind Load 50/33 PSF
ECFM-1	.43	-3.66	.65	90	9	.2	19
ECFM-2	.90	- .46	.95	131	21	.4	40
ECFM-3	1.42	1.52	1.19	165	32	.5	62
ECFM-4	1.95	2.9	1.39	192	43	.5	84
ECFM-5	2.42	3.84	1.56	215	54	.5	107
ECFM-6	2.99	4.76	1.73	239	65	.5	130



HORIZONTALLY POLARIZED FM EDUCATIONAL ANTENNA SPECIFICATIONS

Type No. And Bays	Power Gain	Gain In db	Field Gain	FS @ 1 Mile 1 KW, MV/M	Net Wt. Lbs.	Power Rating KW	Wind Load 50/33 PSF
EHFM-1	1.0	0	1.0	138	9	.2	19
EHFM-2	1.8	2.55	1.34	184	21	.4	40
EHFM-3	2.8	4.47	1.67	230	32	.5	62
EHFM-4	3.7	5.7	1.92	264	43	.5	84
EHFM-5	4.6	6.6	2.1	289	54	.5	107
EHFM-6	5.5	7.4	2.3	317	65	.5	130

Educational FM Antennas are designed to mount on tower legs or support pipes having diameters up to 2¾". The spacing between bays is 10 ft. Educational FM Antennas are fed with 50 ohm cables and all have a type N Male Input Connector.

Cablewave *Transmission Line*

Cablewave Systems Foam Wellflex coaxial cables offer a combination of remarkable flexibility, high strength, and superior electrical performance. The designs include a copper clad aluminum center conductor, low-loss cellular polyethylene foam dielectric, corrugated copper outer conductor and a protective black polyethylene jacket. Foam Wellflex is used extensively in communications and electronic systems in the HF, VHF, UHF and microwave frequency bands.

Type FCC-	Size	Impedance	100' @ 90 mHz Atten.	100' @ 90 mHz Eff.	Average Power Capability	Minimum Bend Radius	Jacket O.D.	Weight per 100'	"N" Connector Required Male	"N" Connector Required Female
38-50J	3/8"	50 Ω	1.0 dB	79%	1.3 kw	4"	.445"	8.7#	738-626	738-627
12-50J	1/2"	50 Ω	0.65 dB	86%	2.2 kw	5"	.610"	15.7#	738-650	738-651
78-50J	7/8"	50 Ω	0.39 dB	91%	5.0 kw	10"	1.08"	47.6#	738-675	738-676

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LPB TECH NOTE #7

CAMPUS RADIO --- FM or AM

Establishing a broadcast station on the campus means choosing between 10-watt Educational FM and campus-limited AM. The decision is too often based upon inadequate information, since Educational FM is more widely known, and AM campus-limited or *carrier current* suffers from bad publicity. This note presents some of the considerations so that you may consider which, systems, or *if both,* are best for your situation.

THE OUTLOOK FOR AM OPERATION

Educational FM is an F.C.C. licensed broadcast service, and is available *only* if a frequency is open in your area. To determine this, and to establish to the F.C.C. that the addition of your proposed FM station will not result in interference to those already operating, your first step will be to retain a qualified broadcast consultant. Expect his bill to be more-or-less a thousand dollars, but it will be well spent. If you are in a major metropolitan area it is very unlikely that even the cleverest consultant will be able to find you a frequency.

If your consultant is satisfied that a frequency is available, he completes your application for a *Construction Permit,* specifying transmitter make, power location, and antenna details. If the F.C.C. accepts all his information as submitted, you may expect to receive your Construction Permit in about 90 days. Then, and not before because you did not have a frequency assigned, you can order the transmitter, transmission line, antenna and tower. Expect this to cost from two to five thousand, depending upon the transmitter you choose and your antenna configuration. Plan on a three-month delivery time, since these are not production line items and your crystal will have to be *aged* by the manufacturer to meet specifications. Installation of the equipment shouldn't take long, and then you may advise the F.C.C. that you are ready to go and request *program authorization,* which should be promptly forthcoming. This timetable is probably a factor in your decision.

Your 10-watt Educational FM station will provide broadcast coverage of all listeners within a few miles radius. Just how far depends upon the antenna choice and height combined with conditions of local topography and soil conductivity. Your consultant can tell you more about this. Higher power levels than 10 watts increase this radius of listenership. Most students have FM receivers in their rooms, so count them in. What will worry your school administration, who *must* sign for the FM license, is what kind of program material you will broadcast to the nearby population. No college president or board of trustees can afford to overlook your potential for the presentation of one-sided or argumentative material. Nor can any college PR man long overlook what he could do with an FM station. All of this spells the possibility of faculty control, a great deal of caution, or even their refusal to go along with your FM station at all. But perhaps you have been operating a campus-limited station for a few years and have demonstrated it to be a responsible operation on the campus. That history can go a long way. And, by the way, it is our experience that the vast majority of campus stations *are* responsible operations.

The Commission and the trustees may let you have your Educational FM operation, and may even scrape up the few thousand dollars for the consultant and the transmission system. Unless you are fortunate to already have good broadcast studio facilities, plan several thousand more here. Five thousand is quite minimum; ten to fifteen more typical but not really elaborate. An FM studio complement can only cost *more* than AM, simply because you cannot "make do" when you have to pass an annual *proof of performance test.* Do not forget the annual operating budget; it is usually higher than you think! As an Educational FM'er you have no advertising income possibilities. This loss of advertising is probably more important a loss of something else than the cash. That something else is the all-too-frequently-forgotten training value that accompanies it. The sale and production of advertising is an important element of training for the real world of commercial broadcasting. In Educational FM, it isn't there. And when you sell spots to an advertiser he expects you to deliver for him; that is a monkey on your back to produce *when* and *how* promised. That is also real world training value not present in Educational FM.

Certain minimum hours of operation and regularity throughout the calendar year are also a part of the licensed station requirement, although the Commission has granted numerous waivers regarding these points to accommodate the vacation schedules of colleges.

One should also consider the future prospects of any new venture. For a 10-watt Educational FM station, the future may offer possibilities of power increases and upgrading to stereo operation. Most stations do not consider the added costs of stereo worthwhile until about 500 watts is reached, but this future power increase is again dependent upon non-interference with other broadcasters. If this type of growth is a possibility in your future, make sure that the 10-watt transmitter you buy has the specs and the F.C.C. type approval for later use in stereo and as an exciter for a higher power final power amplifier stage. Some do not qualify on this score, and not just the cheaper ones.

THE PROSPECT FOR AM CARRIER CURRENT

Turning to a more direct look at campus-limited *carrier current* AM, recognize first that this is an *unlicensed* service ... no application forms and no wait for F.C.C. approval. Part 15.7 of the F.C.C. Rules and Regulations requires only that your system does not interfere with a licensed broadcaster and that you observe certain limits of radiated signal strength. Satisfy these requirements and the local F.C.C. men will never care about you.

Carrier current universally suffers from lack of understanding. Understanding about what it can accomplish *and* about the art and technology of how to engineer it correctly is often sadly lacking. Typical is the college that has witnessed a succession of "experts" over the years, each having spent a significant sum of money on building equipment which has ended up with an unworkable or unacceptable broadcast system. These "experts" may have been very capable people, but they simply did not have the advantage of the needed background in the *art of carrier current systems*. Many competent commercial broadcast engineers have fallen into this same trap.

Broadcast coverage with a carrier current AM system will be limited to the buildings you choose, usually dorms. This means several differences in management and programming compared to Educational FM. Your college PR man and college administration just lost interest and turned over the policy making and monitoring to the student station management. Your programming is now governed only by what the student body is interested in hearing, with no concessions needed for the local population.

We have seen a large number of colleges give up carrier current AM for Educational FM, only to later re-open the carrier current operation as a *training ground for the FM station* as well as for that uniquely campus-oriented programming capability. The AM station thus has a unique purpose on the campus *and* serves as an invaluable base for training personnel before turning them loose on the public via FM.

In carrier current AM the transmission costs are totally dependent upon the campus situation. Figure on an outside cost averaging $350 per building to be broadcast to. The "entry fee" for the AM studio equipment is more favorable since the station can readily begin by utilizing a minimum collection of borrowed and makeshift equipment that would not have met the required FM proof of performance or the broadcasting quality that you would want for AM. This is excellent, for it allows a minimum total investment beginning upon which the value of the operation to the college community can be established before spending large sums on equipment that will be useless should the station prove of little or no value. Once the value of the station is demonstrated, there is nothing like this success to produce a flow of money for decent studio equipment.

There is also nothing like advertising to produce a large part of the annual operating budget. Advertising income from local advertising sales is limited only by your imagination and sales effort. Most carrier current stations provide their advertising sales people with incentive in the form of a commission from sales. The fact that AM can have this advertising makes it a training ground for commercial radio broadcast *of which there is no other equal*. Many carrier current stations bring in ten thousand per year from local advertising time sales.

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We have pointed out that the programming formats of the AM and FM stations will differ, at least in part. This allows some simulcasting and some separate programming. Hours of operation for the campus-limited station can be anything from a few hours per day to continuous, depending upon available talent and interest. Many carrier current stations do provide 24 hour service to the community, either by rebroadcasting the material of a suitable commercial station when not locally originating, or by adding a minimal automation system for after-hours operation.

SUMMARY

This brief review of the considerations of FM vs. AM is complimentary of both, recognizing that they have *differences*. It is clear that AM is probably *quicker, easier and cheaper*. It is also clear that AM is the most logical *place to start*, and that Educational FM is the growth direction to expect after the carrier current operation has been proven and stabilized.

Whatever your particular situation dictates, AM or FM, we at LPB offer you our background in educational radio for whatever assistance you wish.

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LPB TECH NOTE #5A

CONSIDERATIONS IN EDUCATIONAL FM BROADCAST EQUIPMENT

The considerations in the establishment of a low power (Class D) educational FM radio station involve a number of variables and trade-offs. In the following discussion we attempt to point out some of these and provide an acquaintance for the reader who may not be accustomed to the field. Initial guidance is also involved in that all important area of costs.

1.0 General Transmission Considerations

Twenty of the one hundred available FM broadcast channels (88.1 - 91.9 mHz) have been set aside for educational broadcasting. Unlike the commercial portion of the band, there is no Table of Allocations at the present time for the educational band, that is, channels are not set aside for specific geographic areas or power levels. A prospective educational FM broadcaster may consider anything from 10 watts (Class D) to 50,000 watts. As the power of the station increases, the studio and control room equipment requirements will likely increase. More noticeably, the cost of each of the many components of the transmission system will increase sharply. Consider the brief following tabulation of typical transmitter costs alone:

Power	Comment	Cost
10 watt	Solid-state (LPB FM-10SS)	$ 2,490
60 watt	Solid-state (Wilkinson FM-60E)	3,750
100 watt	Solid-state (Wilkinson FM 60E mod.)	3,995
250 watt	One-tube (Wilkinson FM-250E)	5,475
1 kw	One-tube (Wilkinson FM-1000E)	7,950
2.5 kw	One-tube (Wilkinson FM2500E)	11,500
50 kw	Collins 831H-2C	81,350

Ten watt Class D educational broadcasting is obviously the least expensive. Many stations have utilized it as an entry into the field, finding it wise later to grow to larger power levels. This is entirely practical. Initial 10 watt costs are low because:

1) The FCC requires no transmitter monitoring equipment.
2) No encoded responding generator is required under the new Emergency Broadcast System Rules.
3) High quality, inexpensive solid state FM transmitters such as the LPB FM-10SS are readily available.
4) These stations are usually mono, saving the cost of the stereo generator and of the more expensive stereo studio equipment.

Because of the popularity of 10 watt Class D broadcasting, the majority of our following comments will be directed to it. For a 10 watt transmitter we suggest your consideration of the LPB FM-10SS. This is an all solid state unit employing the latest and most foolproof state-of-the-art techniques available in transmitter design. It employs direct frequency modulation with the operating frequency generated by a phased locked frequency synthesized loop based on an 8 mHz reference crystal. The result is foolproof and ultra-stable. This is combined with an output power amplifier which will withstand any abuse to which it can be put. Unlike almost any other available similar transmitter, it will indefinitely withstand any VSWR imposed upon the output as a result of mismatch, disconnection, short, etc. All audio characteristics including stereo characteristics (if the unit is so used) are also second to none. Hundreds of these units are in service throughout the world.

Physically, the FM-10SS occupies two 3½ inch standard relay rack panels. One is the exciter which by itself is Type Approved by the FCC as an exciter for any power level, commerical or non-commercial transmitter. The other is the meter panel which added to the exciter, meets the requirements of a Class D broadcast transmitter. LPB can also supply a variety of relay racks in which the transmitter and associated equipment might be mounted.

The LPB FM-10SS will not become obsolete if the station later grows to higher output power levels. Similarly, it is approved for and has outstanding specifications for both stereo and SCA operation for which companion generators are available.

2.0 Stereo Generator

Left and Right channel stereo audio signals are fed to the stereo generator for processing and then to the transmitter. Since the stereo generator feeds the transmitter exciter, it is a one-time investment and needs no changes if the station later goes higher power. The QEI/LPB Model 772 Stereo Generator displays excellent stereo performance specifications and outstanding pilot stability at only $895. Another fine stereo generator is the Orban Optimod Model 8000A, which combines an excellent stereo generator in a single package with outstanding stereo compression and limiting amplifiers. The price of the Optimod, which is extremely low considering all it combines, is only $3,195.

3.0 The Transmitter and the ERP

The Effective Radiated Power of an FM station is the transmitter power output less transmitter-to-antenna transmission line losses times the power gain of the antenna. Depending upon the choice of antenna, the power gain may range from 0.45 to possibly as high as 17, clearly making the antenna an extremely important factor in the station's signal strength. This may suggest buying an antenna of higher power gain but there are many factors to consider.

In FM the advent of the car receivers which use vertical antennas has required the FM broadcaster to transmit in circular polarization wherein the available signal is divided between horizontal polarization (to which most home and portable receivers are sensitive) and vertical polarization (for the benefit of the car receiver). While most educational FM broadcasters use circular polarization, many cases may warrant consideration of the value of the motorist listener as he curtails the amount of power radiated in the horizontal plane and hence the useful range of the station to home receivers.

A single bay (or single element) horizontally polarized antenna is the frame of reference with a power gain of unity. A single bay circularly polarized antenna has a typical power gain of about 0.45. Both such antennas would radiate energy equally well in all directions of a vertical section cut through the antenna. The energy which is directed steeply upwards and downwards can be concentrated into a more nearly horizontal pattern by using a multiple bay antenna. This may have another advantage in the reduction of strong signal directed to nearby large buildings if the antenna is located in urban areas. This near-in strong signal radiation can cause annoying reflections and multipath reception. If the antenna is atop a mountain beside the town, one can visualize that a null area could be created by the use of multiple bays. The solution to this is called beam tilt though this modification to an antenna is generally not available for low power antennas.

The elements of an FM antenna are typically spaced ten feet apart. Therefore the vertical extent of a multi-bay antenna coupled with the requirement to raise the bottom bay at least ten feet above the structure upon which the tower is located means that additional bays require additional antenna height. The additional weight of these bays and the additional wind loading may also dictate an increase in the tower strength. For low power antennas the feed point at which the upper end of the transmission line from the transmitter must connect is the center point of the bays. This requires added transmission line length as the number of bays increases. Note, however, that most medium and high power antennas have a power divider located at the bottom, hence, this added transmission line length is not a requirement at higher powers.

The typical antenna for a Class D station is two or three bays. The following tabulation will be an interesting comparison of antennas.

Bays	Comments	Cost
1	Horiz. or circ., 200-watt limit	$ 225
2	Horiz. or circ., 400-watt limit	450
3 & up	Horiz. or circ., 500-watt limit	225/bay
1 & up	Horiz. or circ., 1-kw/bay limit	400/bay
1	Circular 5-kw limit	800
1	Horizontal 5-kw limit	770
2	Circular 10-kw limit	1,265
2	Horizontal 10-kw limit	1,200
14	Circular 40kw limit	11,890

4.0 Antenna Towers

If a single bay antenna is your choice, it will probably be entirely practical to mount it on a simple ten foot TV antenna mast purchased at the local TV shop and strapped to a chimney atop a building. Multiple bay antennas will certainly require a tower. We have discussed this above. Note also that as the tower height increases depending upon your proximity to a nearby airport, the FAA may require aircraft collision avoidance lighting. This can easily double the price of a tower.

For a few bays the Rohn 25G Series light weight towers are usually adequate. Larger antennas especially in windy locations and where lighting is required, dictate upgrading to the Rohn 45G Series. Some typical prices follow:

Height	Comment	Cost
40'	25G, weighs 270 pounds	$ 414
50'	25G, weighs 315 pounds	472
50'	25G, weighs 500 pounds	710
60'	45G, weighs 575 pounds	797
70'	45G, weighs 650 pounds	882

The Pi-Rod Company also makes an interesting line of totally self-supporting towers which are welded from solid steel members. They can be finished so as to never require repainting and can be made in sectional lengths that can be brought to the top of your building in conventional passenger elevators. These Pi-Rod towers are more expensive but in some rooftop applications the inability or impracticality of guy points and guy wires may leave no alternative. We can supply all of these styles and would be pleased to review your requirements and make specific recommendations.

5.0 Transmitter Frequency and Modulation Monitoring Equipment

In recent years the FCC has deleted the requirement for frequency monitoring instruments in radio stations. This is a result of the improvements that have been made in the stability of broadcast frequency generation techniques as is epitomized by the phase locked loop technique in the LPB solid state transmitter.

All broadcasters other than Class D educational FM require an independent instrument for the monitoring of modulation percentage. As an example of cost, the Belar FMM-1 is $1,550. If the station is stereo, the additional Belar FMS-1 stereo monitor adds $1,350.

6.0 The Emergency Broadcast System

In recent years the FCC has overhauled the Emergency Broadcast System and now requires that all FM stations monitor the new EBS system. Class D educational stations are exempted from the requirement of the transponding tone generator but are required to have a Type Approved fixed frequency monitor receiver and a similar decoder which upon recognition of the appropriate tone codes will activate an alarm.

With the receipt of your Construction Permit from the FCC, you will get an EBS monitoring assignment. This will be a nearby AM or FM station keyed to the EBS scheme of things which you are to continually monitor. The receiver and decoder typically cost about $200. For other than Class D stations the additional transponding generator adds about $250 to the bill. We can supply several varieties of these depending upon the requirement.

7.0 Remote Control

The Commission's Rules require that if the transmitters are not "readily visible from the operator's position" a remote control system must be employed to remotely control and fully meter the transmitter. The remote control linkage may be either wire line or radio and the price of a typical Moseley, Marti, TFT remote control system can run from $2,500 to $10,000.

Once again, the Class D educational FM station is the exception to the Rule. The Commission will allow the location of a 10 watt transmitter away from the studio, probably up under the antenna base for reduced transmitter-to-antenna transmission line losses. In this case only the prime power to the transmitter must be remoted from the studio. This degree of control is a rather simple matter and may be accomplished by a simple pair of control wires between the studio and the transmitter.

8.0 Transmission Line

We have also spoken frequently of the transmitter-to-antenna transmission line. It is clear that we wish to convey as much as possible of the transmitter output power to the antenna. The cost effectiveness of the transmitter is but another of the trade-offs in the design of an FM station. Let's take a brief look at this in the tabulation below of standard RG-8/U and three different types of Cablewave (Phelps-Dodge) foam "Wellflex" (equivalent to Andrews "Heliax") transmission line. The standard length of 100 feet at 90 mHz with a ten watt is used.

Type	Watts to Antenna	Cable Cost +	Connector Cost =	Total Line
RG-8/U or -8A/U	6.6	$ 20	$ 4	$ 24
3/8" Wellflex	7.9	70	28	98
1/2" Wellflex	8.4	88	19	107
7/8" Wellflex	9.0	220	50	270

The comparison of low-loss transmission line with ordinary RG-8/U coaxial cable is bad, as it should be. With only 50' of RG-8/U, about 8.1 watts are delivered to the antenna. This makes it clear that the economy of RG-8/U is realistic for transmitter/antenna separations of less than 50', but for greater lengths a low-loss transmission line is called for.

Which size Wellflex you buy is, again, that trade-off of transmitter power conservation versus cost. It is clear that anything larger than 7/8" is a poor investment, for the price is now mounting very rapidly. It is interesting to plot cable efficiency versus cost of cable plus connectors. A glance at the curve is another way of interpreting the above; it shows clearly that 1/2" Wellflex is a best buy. It is also a quite practical size to work with. We will be pleased to provide an analysis for your particular situation requirements.

9.0 Cost Outlook

This LPB Tech Note was written to furnish you some initial terminology and and an introduction to some of the trade-offs which govern the choices of equipment for a 10 watt educational FM station. We know that cost is one of your most basic considerations. What's the outlook?

A basic, yet professionally equipped, 10 watt mono FM station may be expected to require an initial equipment budget of about $15,000. This will be divided about 60/40 between studio and transmission equipment. Budget another $1,000 for the broadcast consultant to find you an available frequency and prepare the documentation for your Construction Permit application. If you must start with a really minimum operation, you may be able to shave as much as 20% from these figures. But, if you are on a very tight budget, it would be well to honestly review the wisdom of trying to start a broadcast operation. Will you be able to support the operating costs? We have seen inadequately backed stations fail in a year or two because of this. In the other direction, about $20,000 for equipment will get you a moderate, professionally equipped station with a solid state mono transmitter. The largest part of the increase is in the elaboration of the studio.

Everyone's actual requirements will differ. We at LPB would be pleased to have the opportunity to learn your specific needs and provide a detailed equipment budget.

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AUDIO LINES FOR COLLEGE STATIONS

Audio lines, or phone lines, are an everyday part of the operation of every college station, yet constant problems exist in their understanding, selection and use. This Tech Note will present an introduction to some of the considerations.

LINE QUALITY

Audio lines are used in the college station to bring in remote broadcasts from away sports events, and to provide an interconnect between the control room and the transmitter. Carrier current stations, with audio lines to each of their several satelite transmitters, are particularly concerned with the cost and value received from these circuits. The following comments are particularly applicable to lines on long-term lease by the college station, often called dedicated lines.

Dedicated audio lines are available to meet a number of transmission quality specifications, described as the *class* or *rate* of the line. Perhaps the most common are:

class 6003 ± 1dB from 200Hz to 3,500Hz
class 6005 ± 1dB from 100Hz to 5,000Hz
class 6007 ± 1dB from 50Hz to 8,000Hz
class 6009 ± 1dB from 50Hz to 15,000Hz

These quoted class designations are peculiar to lines leased for continuous service. Different designators would apply to lines of similar specification rented for short-term use. The specification is a minimum quality guarantee. If you ask for a 6007 line from the studio in the student center to a transmitter in a dorm across the campus, the phone company will dedicate a phone pair from the campus telephone service for this and will send out a crew to measure its performance. If they find it meets 6007 specifications without need for equalization equipment, your station gets the line for about $24 per month plus a $30 installation fee *if* you are a *licensed* station (see further discussion of this point below). The total length of wire in this on-campus audio pair may only be a few thousand feet. It should be no surprise if such a line needs no equalization to be good to 8kHz. Suppose you had ordered a 6003 line, at $10 per month plus a $15 installation fee, and spent 30 minutes of your own time checking frequency response. One of these three alternatives would result:

1. You found it really meets 6007 or better specs. Odds *for* this are excellent for an on-campus run. Savings is $168 per year plus $15 installation *per audio line*.

2. You find the line does not meet your desired spec, so spend another 30 minutes with a few dollars worth of small parts to equalize the line to meet your needs. Same savings, Or,

3. You find the line does not meet your desired spec, so called back the phone company to revise the order to 6007. This costs you 30 minutes and $15 more than if you had ordered the 6007 line at the beginning, but the difference is now you *know you need to pay* the added price.

LINE COSTS

We have referenced some costs, and now we are getting to one of the punch lines in this phone line business. Note the reference to $24 per month for a 6007 line IF you are a *licensed* station. A (licensed) educational FM station is considered to engage in interstate commerce, hence is subject to standard interstate tariffs on file with the F.C.C. and the I.C.C. Even so, on the *same premises* (campus) the rate between *different buildings* may be lower than the rate between buildings on *different premises* (off-campus fraternity). For the carrier current (UNlicensed) station the rates may be expected to be *even lower*, because this station is obviously engaged only in *intra*state commerce; the F.C.C./I.C.C. interstate tariffs no longer apply. What does apply is an *intra*state tariff which is non-standard, but is *guaranteed* to be substantially below the interstate.

If yours is a carrier current station, the heart of your problem is simply that of being billed under the *appropriate tariff*. Very naturally the member of your staff who calls the phone company to order a line will identify himself with "...radio station WXXX at Brown College...", hence it should be no surprise that the phone company personnel identify WXXX with the *inter*state tariff. These people are not knowledgeable of carrier current radio, and by the basic nature of your identification you have, unintentionally, misdirected them. Properly, carrier current stations are subject to something usually termed *Private Channels for Music Transmission in Connection with Sound Recording or Loudspeakers*.

This is under the intrastate tariff which is probably based upon airline mileage between end points, with another reduced *on premises* rate. While variable from state to state and phone company to phone company, the intrastate rates are universally more favorable to the budget of the carrier current station. If your station is being billed under the higher interstate tariff, it would not be correct to blame the telephone company. You are a rare type of user with whom they are not immediately familiar, especially when you identify yourself in the manner of a licensed radio station.

LINE REQUIREMENTS

If a college radio station is both licensed educational FM *and* carrier current AM, the appropriate rate for each line must be based upon what *that particular line* is used for.

You can see that a carrier current station with several transmitters can save a lot of money being sure that it is billed at the *correct* rate *and* that it buys no more expensive lines than are needed. For AM carrier current, what frequency response is worth paying for? Sorry hi-fi fans, but anything beyond the 6005 line is a waste of money. The FM station, however, can justify the 15kHz response of a 6009 line.

When an audio line is required, the best approach is to locate the technical man in the phone company who is cognizant of this specialty area. Ask for the engineer who handles "radio loops," and don't be too discouraged when the first six persons you are directed to clearly do not have the least bit of understanding what you are talking about! Suddenly the right person will fall out if you shake hard enough. This can be very rewarding, for stating what your end point requirements are will invariably allow this person to tell you exactly what the line routing will be. This goes a long way toward defining the expected quality before any attempts to equalize. Based upon such a discussion, it may be best that you order the cheapest line available, which may be an undefined class below that of 6003, and do any needed equalization yourself.

Sometimes this cheapest form of on-campus line is called a *DC pair*. As the name implies, this pair would be free of any amplifiers or repeat coils so that it will pass direct current. Be aware, however, that sometimes one pays *extra* for a DC pair, especially if to achieve DC continuity takes extra work or special routing on the part of the phone company, *or* if you are going to use it for control of the transmitter *in addition to* program transmission. Dual function use of a pair increases the applicable tariff.

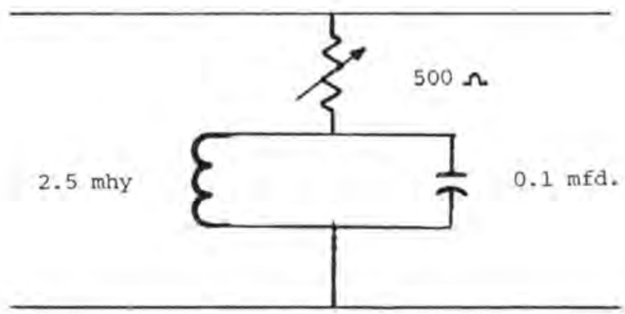
EQUALIZATION

Equalization is the modification of the electrical vs. frequency properties of an audio pair to improve the high frequency transmission. Shunt capacity is the property of the line which causes loss of highs. An example is a 4 mile loop (2 miles between end points) which, when terminated with matching 600 ohm impedances at both source and load, would typically display 6dB loss at mid-band (1kHz). It would be expected to display 9dB loss at only 1.5 kHz, hence is down 3dB at 1.5kHz.

Perhaps the simplest available form of equalization would be to match the source and load both at 150 ohms. This reduces the shunt capacity effect and moves the -3dB point out to about 3.5kHz. Just changing the termination to 150 ohms is the first step in simple equalization to reduce the effects of cable shunt C. The phone company does this by inserting repeat coils at either end. These are simply 4:1 transformers to reduce the drive and loading impedances from 600 to 150 ohms.

The next step the phone company would take is to add 88mHy series inductors at about 6,000 foot intervals along the cable to cancel the capacity. In the case of 6007 and 6009 lines, smaller inductors of about 5.5mHy would be added at intervals of about 3,000 feet. As users we have no such access to the cable, other than at end points.

While it is not the objective of this note to present a complete discussion of equalization, the following passive equalizer circuit is one that may be added to the load end of the audio pair:



This equalizer is designed to maintain good response out to about 8kHz. This is accomplished by *adding* mid-band attenuation to bring *down* the mid-band response *to equal that of the high end*. This means that all passive equalizers, of necessity, increase overall line losses. Be sure the equipment on the other end of your audio line has the reserve gain to be able to work with the added loss.

The procedure for adjusting the equalizer is quite simply as follows: 1) Set R at maximum. 2) Place an isolation pad of at least 6dB between the drive source and the line input to eliminate any erroneous readings due to line impedance vs. frequency effects. 3) Measure the line *loss* at 8kHz. 4) Set the generator to 1kHz. 5) Adjust R for the *same 1kHz loss as measured at 8kHz*.

INPUT LEVELS

The standard input level to audio pairs is +8dBm (6.3mW of sine wave power or 1.94v RMS) *at the input connection point*. In almost all broadcast audio consoles this corresponds to the VU meter reading 0 VU. Beyond this input level one must expect crosstalk into other pairs in the same cable. Even at +8dBm crosstalk is sometimes experienced on non-equalized pairs (the mid-band is not attenuated, as described above), hence input levels must be reduced, perhaps to as low as 0dBm.

PRESERVATION OF THE PAIR

How many college stations have returned from summer vacation to find no audio pair remaining between the studio and their transmitters! The problem is simple; idle circuits were presumed by the phone company technician to be no longer in use and were disconnected for other requirements. The solutions are also simple: 1) Never leave a line unterminated, always connect a 10K ohm resistor across the load end so that you and the phone company "find something there" and can make continuity measurements whenever questions arise. 2) Over the summer months place a 0dBm level of standard tone frequency, say 1kHz, on your lines to let everyone know they are in service. A one-frequency tone generator for this is a very simple project.

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