A NEW HIGH POWER
CIRCULARLY POLARIZED FM ANTENNA

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Summary

The BFM antenna is a new circularly polarized antenna developed by RCA to meet the needs of FM broadcasters for high input power in tower top and side mounting applications.

This antenna evolved from the side firing helix design originated over ten years ago with the introduction of the BFC antenna.

The antenna features 18 kW per bay power rating, useable bandwidth of 5 MHz and a good impedance stability with icing.

Horizontal pattern circularity, axial ratio, and impedance measurements are discussed.

Introduction

The BFM series of antennas were developed to provide circularly polarized FM service for applications requiring high power per bay performance. As an example, a 3-bay BFM antenna can be used with a 40 kW transmitter to provide 50 kW ERP in both horizontally and vertically polarized components. This may be advantageous in cases of limited aperture space.

The antenna is a side firing helix composed of four half wave dipoles each formed as a half-turn helix (figure 1). The design of this antenna is an extension of the BFC antenna[1] introduced in 1967.

The bays are stacked vertically at approximately λ spacing for the desired vertical gain. The gain in each polarization is approximately n/2 where n is the number of stacked radiators. A tapped feed system using 3-1/8" rigid transmission line is used for most applications. However, a branched feed system is available for special multiplexed applications.

Operating Principle

The theory of the circularly polarized BFC antenna has been described.[1] As most of you know, the BFC radiator has two half wave dipoles formed in the shape of helixes and these are mounted on a feed stem as two interlaced helixes much like a double threaded screw.

In like manner, the BFM radiator can be visualized as a four threaded screw. The four helically shaped dipoles are mounted on a feed stem which in plan view is shaped in the form of a cross (see figure 2).

The four dipoles are driven in parallel through a ceramic feed point insulator at the center of the cross. A modified delta match feed is used for each dipole.

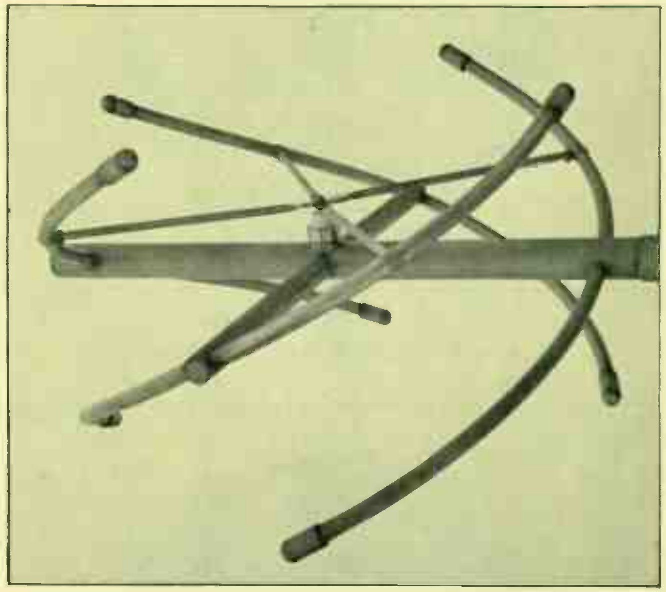

Figure 1 - BFM Circularly Polarized Antenna Radiator

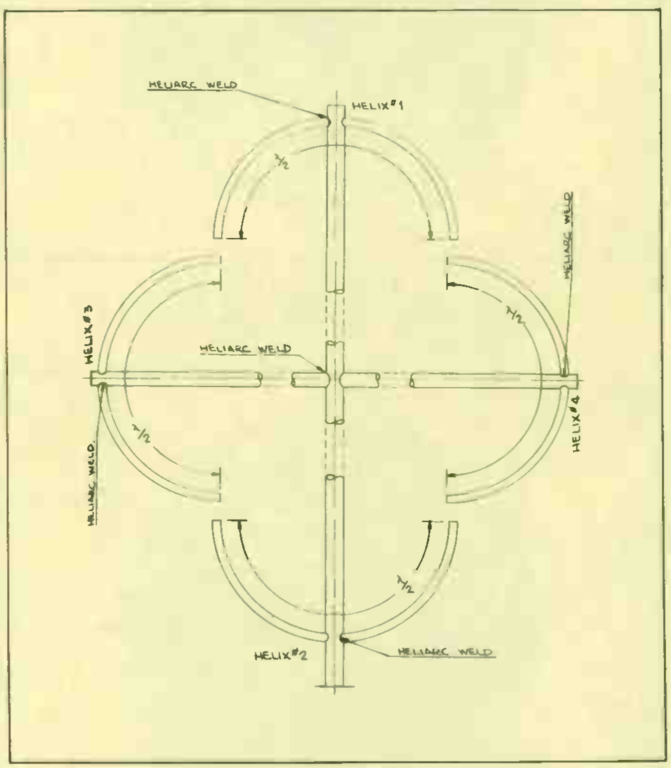

Figure 2 - Heliarc Welding to the Cross Backbone Provides Rigid Mechanical Support

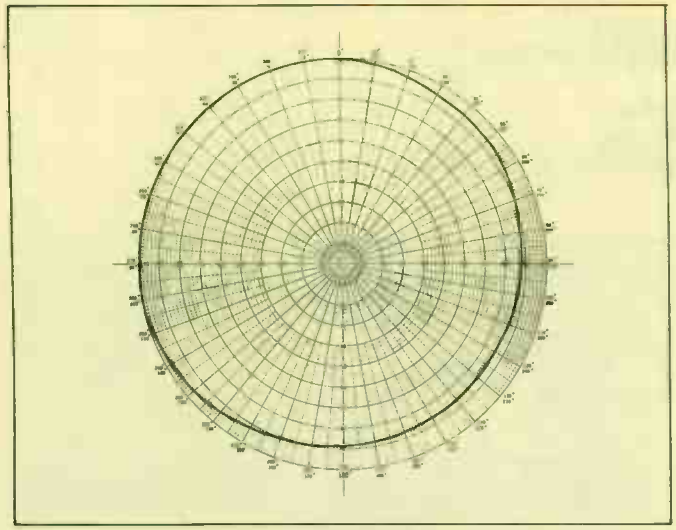

Figure 3 - Horizontal Pattern - Horizontally Polarized Component

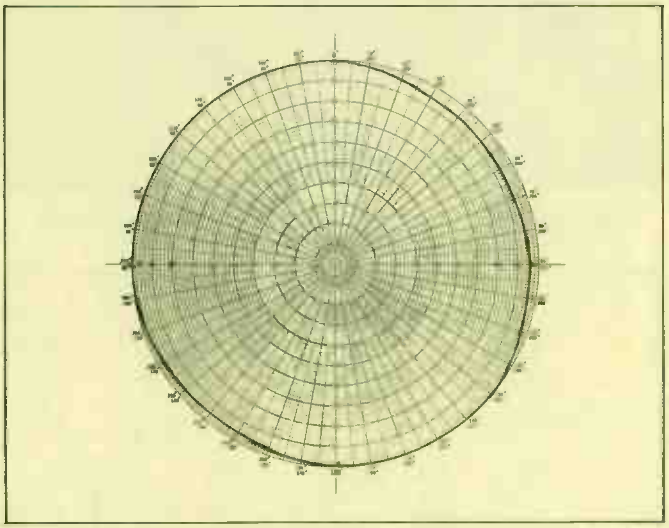

Figure 4 - Horizontal Pattern - Vertically Polarized Component

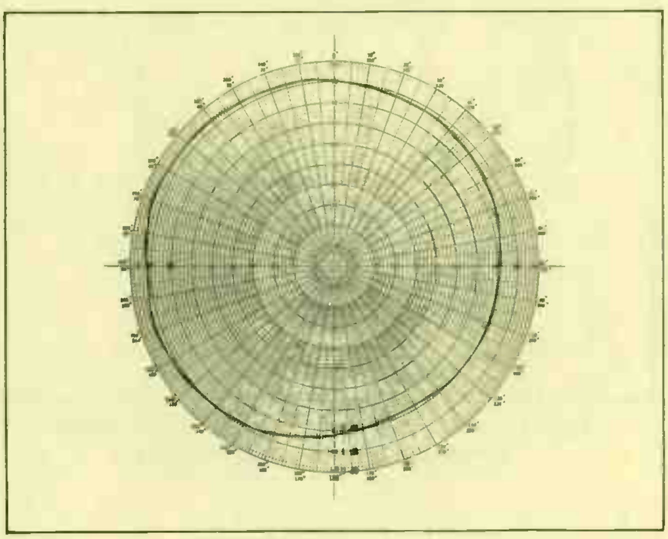

Figure 5 - Axial Ratio

A helix diameter of about 0.3λ is used with a height of about 0.24λ. These dimensions were chosen to provide good omnidirectional pattern circularity (figures 3 and 4) and low axial ratio (figure 5). Measurements were taken in about 1/4 scale with the BFM radiator model mounted on a fiber-glass pole in accordance with techniques described.[2,3]

Design Features

The dipoles are fabricated of 1" diameter 304 stainless steel tubing. The 2-1/2" diameter feed stem and cross arms are also stainless steel.

Dipoles are attached to the support cross by heliarc welding. The midpoint of the resonant dipole being at zero voltage serves as an excellent point for simple rugged mechanical support.

RF voltage probing tests were carried out on the radiator to determine the magnitude of highest voltage gradient at rated input power. This was found to be at the dipole tips as expected and with a value of 1,000 volts/cm with 30 kW input power. A generous margin of safety has been provided against 30,000 volts/cm dry breakdown value for air and also against the 6,000 volts/cm wet breakdown value found in a U.S. Navy study.[4] In addition, low frequency, high voltage stress tests were performed on the feed stem and end seal. These coupled with the probing tests support the peak input power rating of 30 kW for the antenna. Evaluation of feed stem heating showed adequate margins at an average power input of 18 kW.

Implications of Power Rating

The average power rating of the BFM antenna has been shown to be 18 kW per bay.

This means that for an application requiring 50 kW ERP, a 3-bay antenna can be used with a 40 kW transmitter assuming the transmission line losses are not abnormal.

Further, this means that for an application requiring 100 kW ERP and separate transmission lines to upper and bottom halves of the antenna, a 6-bay, gain of 3 antenna can be used with a 40 kW transmitter feeding both halves through a power dividing tee. Additionally, full transmitter power can be applied to either half of the antenna providing 50 kW standby ERP.

From the RF voltage probing tests, low frequency stress tests and other considerations, a peak power rating of 30 kW per bay has been established for the BFM antenna. This peak power rating is of significance in multiplexed arrangements where more than one station is to be broad-casting from the antenna. As will be shown, the BFM antenna has a useable bandwidth of 5 MHz.

Three stations with assigned frequencies falling within a 5 MHz segment of the band can be multiplexed on the BFM antenna. A typical example follows:

Required ERP	= 100 kW per station
Number of Bays	= 8
Gain	= 4
Antenna Power Input	= 25 kW per station
Total Power Input	= 75 kW
Power per Bay	= 75/8 = 9.4 kW
Antenna Peak Power Input	= n^2 x 25 kW
	= 3^2 x 25 kW
	= 225 kW
Peak Power per Bay	= 225/8 = 28.1 kW

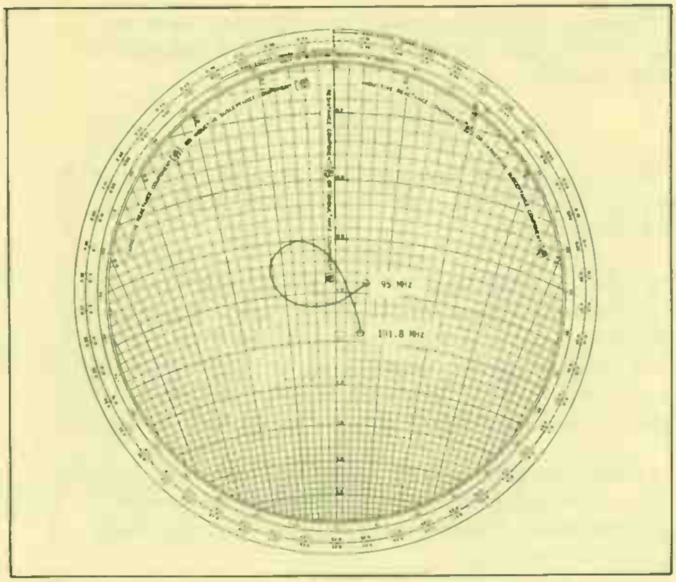

Figure 6 - Bay Impedance Showing Bandwidth Capability

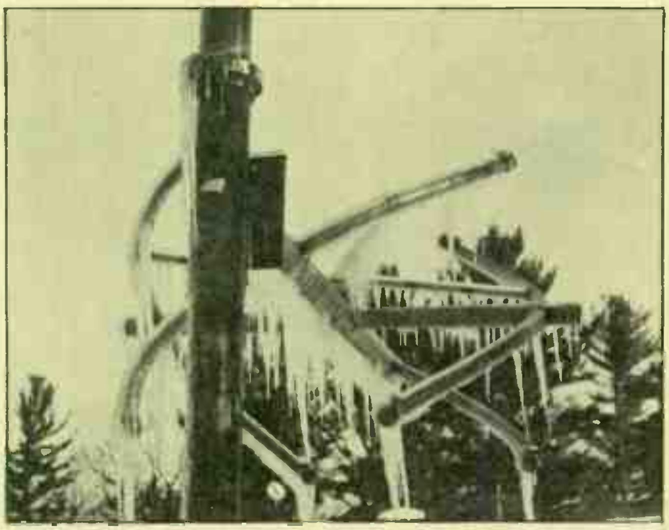

Figure 7 - BFM Antenna with Icing

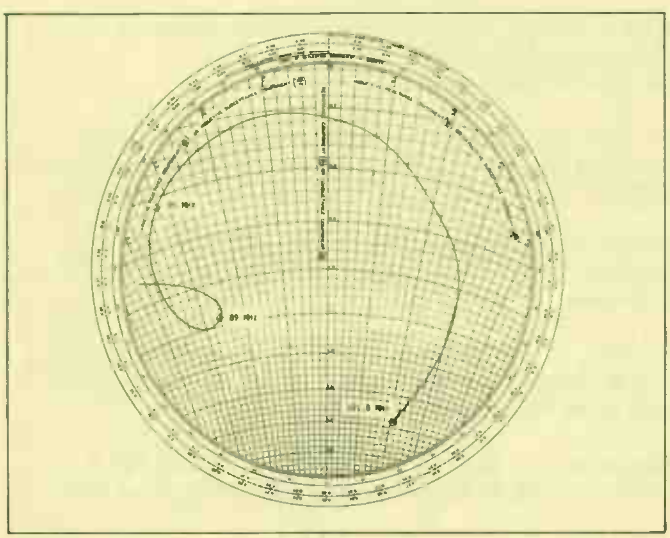

Figure 8 - Bay Impedance with 1/2" to 3/4" Radial Ice

Thus an 8-bay BFM antenna can accommodate three stations to produce 100 kW ERP for each station.

Impedance Bandwidth and Stability with Icing

Figure 6 shows the typical bandwidth of a BFM radiator to be some 5 MHz within a VSWR of about 1.1.

To determine the impedance stability under icing conditions, two types of tests were performed.

1. Simulated icing by wrapping material of a dielectric constant of about 2.3 around the portion of the radiator with greatest sensitivity.

2. Actual icing by using a fine mist spray on the radiator at a temperature of below freezing.

The second test may be rather impressive (see figure 7). Ice was built up to a radial thickness of 1/2" to 3/4" with 8" to 12" icicles bridging the elements and covering the feed-point. The impedance (figure 8) remained within a VSWR of 1.5 over the 5 MHz band.

Despite this seemingly representative test, deicers are available and are recommended for the BFM antenna for areas in which icing conditions are known to occur. The reason for recommending deicers is that a worst case icing model may be available to structural designers for determining the effect of added weight and/or windload on a building, but such a model remains elusive for antenna designers.

Multiplexing Arrangements

One of the simplest arrangements for diplexing two stations on a common antenna is by the tee combiner shown in figure 9. This is composed of two resonant coaxial cavities

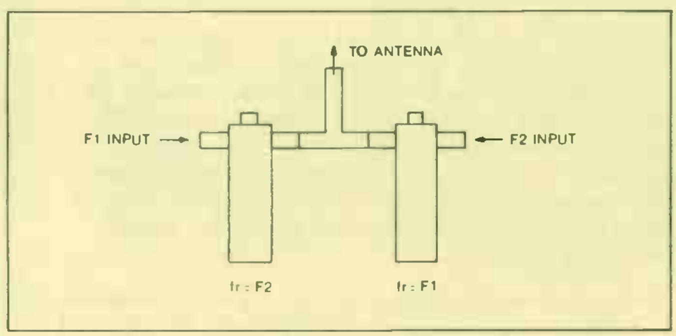

Figure 9 - Block Diagram - Tee Combiner

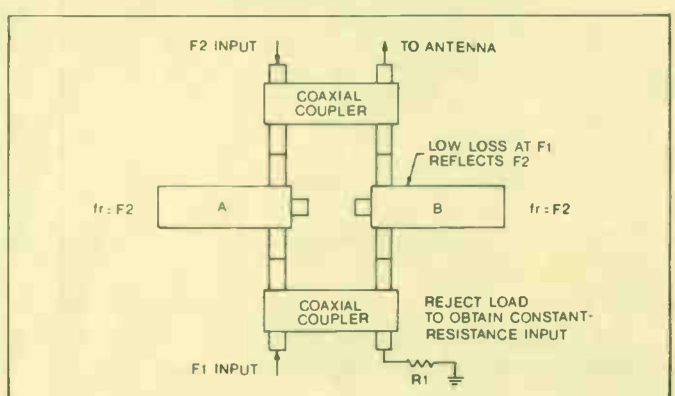

Figure 10 - Block Diagram - Notch Diplexer

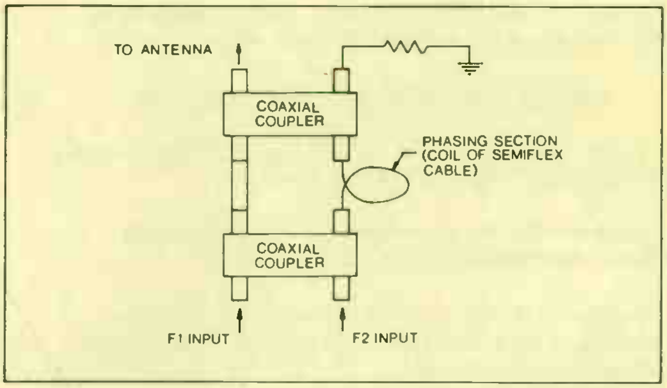

Figure 11 - Block Diagram - Non-Resonant Combiner

and a tee. One cavity passes input frequency F1 but reflects frequency F2 to the antenna. The second cavity passes input frequency F2 but reflects frequency F1 to the antenna.

A second common arrangement is the notch diplexer, composed of a pair of coaxial cavities both resonant at one of the two frequencies to be diplexed and a pair of hybrids (see figure 10).

Input signal F2 is split in Hybrid #2 into two equal level signals but which differ in phase by 90° and are delivered to cavities A and B respectively. Here the signals are reflected back to Hybrid #2 of such phase relationship that the two signals are added and delivered to the antenna port of Hybrid #2. Input signal F1 passes through cavities A and B and the hybrids with little impairment.

A third form of diplexing is by the run-out combiner or non-resonant combiner. This consists simply of two hybrids and a phasing section connected as shown (see figure 11).

A fourth form of diplexing can be used with antennas which have two inputs for quadrature phased signals (see figure 12). Note that this is the commonly used form in TV stations for feeding visual and aural signals to horizontally polarized superturnstile antennas. When this method of diplexing is used for diplexing on some circularly polarized FM antennas, radiation for one station will be right-hand circularly polarized, but for the other station will be left-hand circularly polarized.

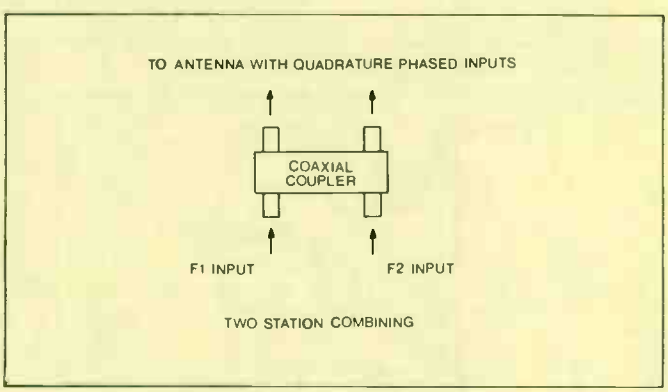

Figure 12 - Block Diagram -
Diplexer for Quadrature Phased Antenna Input

Figure 13 illustrates a method of diplexing when the antenna array is split vertically into two halves and must be driven in phase.[5]

Conclusion

The BFM antenna promises to meet a need of FM broadcasters for high input power per bay in cases of limited available aperture.

Further, the high peak power rating of 30 kW per bay and bandwidth of 5 MHz makes the BFM antenna an economical choice as a shared antenna in a multiplexed system. A brief outline of the basic building blocks in diplexing arrangements has been given. These can be used in combination to multiplex as many stations as required on a shared antenna.

Finally, the BFM antenna impedance under icing conditions is remarkably stable. However, deicing equipment is available for these antennas and is recommended for areas where icing is expected.

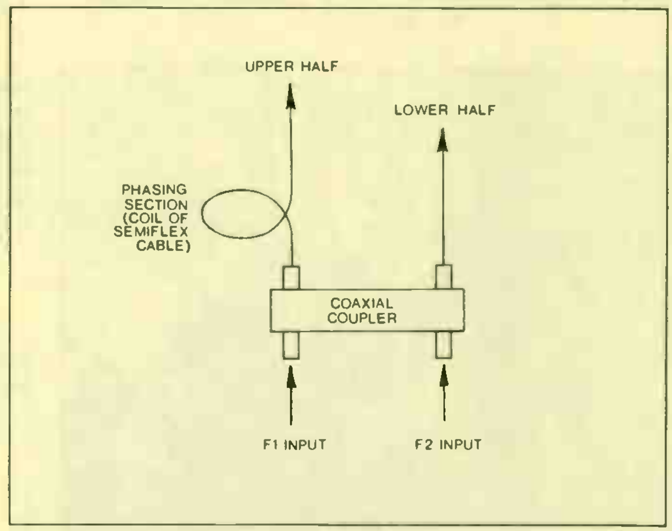

Figure 13 - Block Diagram - Diplexer for Split Fed Antenna

References

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3. Siukola, M. S., "Pattern Optimization of FM Antennas", reprinted from Proceedings of 1976, NAB Engineering Conference.

4. Richards, C. N., "A Study of Insulator Breakdown under Navy Antenna HV RF Conditions", Report No. CR75.001, Dept. of Navy, on Contract N62399-73-C-0033.

5. Siukola, M. S., "New Multi-Station Top-Mounted FM Antenna", IEEE Transactions on Broadcasting, June 1977.