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Development of a JTRS/ SINCGARS Ultra-Broadband Airborne Blade Antenna

By Joseph R. Jahoda
Astron Wireless Technology, Inc.

This development case history describes the design process used to meet requirements for antennas mounted on subsonic aircraft and helicopters.

How do you design, develop, and produce an airborne blade antenna to cover 30 to 2,000 MHz and achieve greatly improved performance, especially at the low end of the band for SINCGARS applications, while maintaining its small size for mounting on sub-sonic aircraft and helicopters? Astron has had a series of R&D and production programs over the past nine years, achieving miniaturized antennas for communications and Direction Finding (DF) Arrays for the U.K., US Army and Navy, Australia, and others for submarines, ships, UUV/UAV, aircraft and Land Mobile systems.

The resulting Astron antenna and direction finding array technology has, over the years, evolved into Astron's HESA™ technology. This unique and proprietary set of advanced techniques provides for high efficiency, sensitivity, and accuracy in all our miniaturized and standard DF antenna systems. A major benefit of the HESA platform includes the ability to co-locate multiple antennas and their associated electronics in a small package; oftentimes exceeding but always maintaining performance parameters equal to their larger counterparts.

The HESA technology applied to the miniaturized JTRS/SINCGARS blade antenna, stresses:

Antenna Size

To operate at the lower frequencies (where antenna height is much less than $\lambda/4$) we can expect lower gains. As an example, at 30 MHz $\lambda/4$ is 8.3 feet. We are allowed about 18 inches for the airborne blade height. The antenna, being much shorter than $\lambda/4$ at 30 MHz, will high VSWR and the required broadband matching networks will result in attenuation and decreased gain.

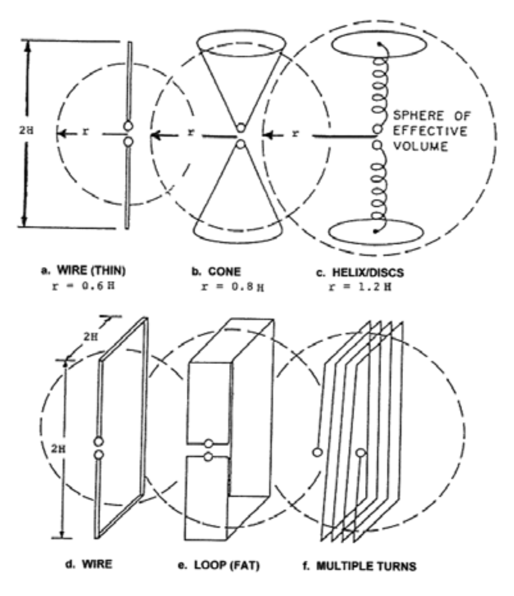


Figure 1 · Effective radius of radiation for various antenna elements.

It is obvious that, certainly at the lower frequencies, in order to increase the antenna gain, it is essential that the antenna be miniaturized. It was, therefore, important to examine the fundamental limits and parameter trade-offs involved in antenna size reduction. First we need to evaluate the size versus operating frequencies and bandwidths of conventional antennas. This analysis is based on the work of the Astron and

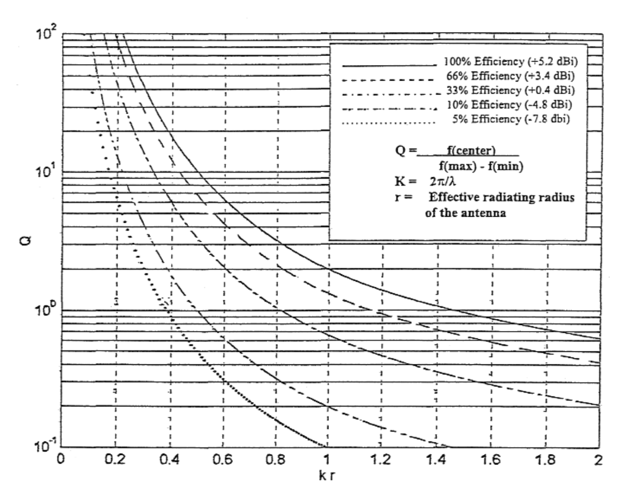


Figure 2 · Chu-Harrington Criteria—The plot illustrates the interrelationship between effective radiating radius (volume) of the antenna structure and bandwidth/efficiency.

Virginia Polytechnic Institute (Professor Warren Stutzman) team performed on a recent DAPRA antenna miniaturization program.

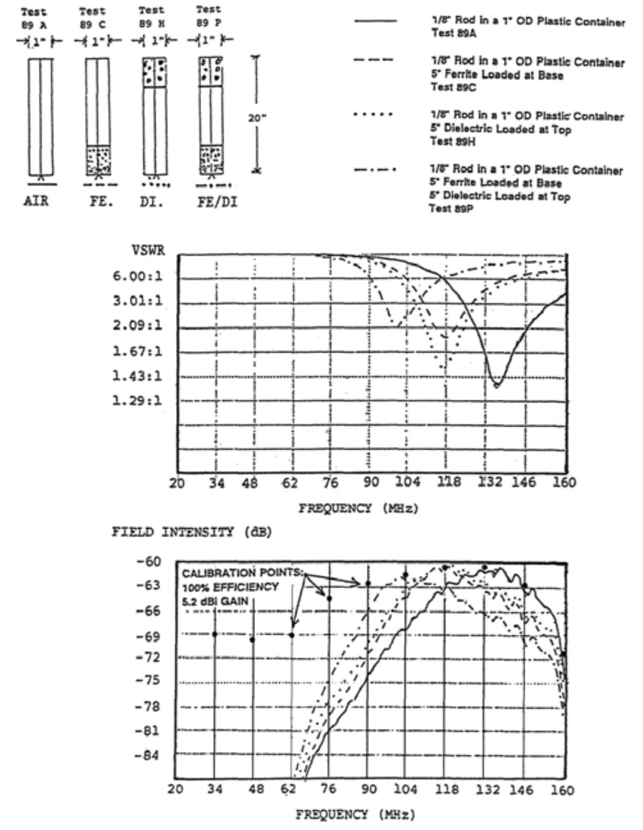
The size of the antenna is measured by the radius, *r*, of a sphere that just encloses the electrical radiating area of the antenna and its ground plane mirror image [1,2]. This size should be measured as an electrical size, which is the principal size relative to a free space wavelength, λ (see Figure 1).

The radiation characteristics of electrically small antennas ($r<0.16\lambda$) was first investigated by H.A. Wheeler [3]. One year later, L.J. Chu [4], derived an approximate expression for the minimum radiation Q of a small antenna. In 1960, R.F. Harrington [5] extended Chu's theory to include circularly polarized antennas. Shortly thereafter, R.E. Collin and S. Rothchild [6] and R.L. Fante [7] derived exact expressions for the radiation Q based on evanescent energy stored around an antenna.

To provide closure on the history of these important concepts, it is to the credit of R.C. Hansen [8] that he assembled, integrated, and promulgated much of this information. These corrected and refined relationships are plotted in Figure 2.

The efficiency family of curves includes the dependence of antenna radiation efficiency, η. The top curve is for 100% radiation efficiency. It shows that for a small electrical antenna, say for $Kr<1$, Q increases dramatically as size is reduced.

To utilize the curves of Figure 2, a point is located for the antenna Q (center frequency of the operational bandwidth) and the antenna's value of Kr at the center frequency of operation. The enclosed radius, *r*, of the antenna is based on the antenna configuration's effective aperture area (see Figure 1) and includes any image of the antenna in the ground plane.



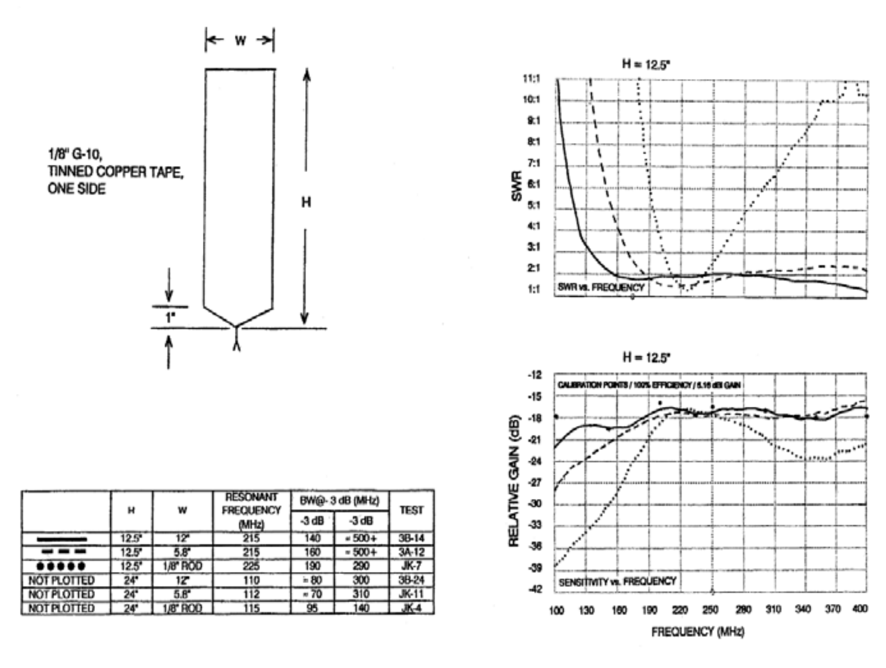
ANTENNA LOADING	FREQUENCY RES.	Bw (-dBi)
Air	135 MHz	30 MHz
5" Ferrite (Base)	118 MHz	28 MHz
5" Dielectric (Top)	118 MHz	30 MHz
5" Ferrite/5" Dielectric	98 MHz	30 MHz

Figure 3 · Optimum dielectromagnetic loading of monopole antennas.

Astron has been using these curves in many of its R&D programs for DoD and found them an excellent guide in determining the potential gain, bandwidth, Q, efficiency, etc., for advanced designs and recognition of the point during antenna developments at which further efforts will not provide any significant improvements in bandwidth and efficiencies unless dielectric and/or ferrite loading is used. The use of this type of loading is the only way to defeat Chu-Harrington Criteria.

Antenna Miniaturization—Dielectric/Ferrite Loading

To illustrate the use of this powerful dielectric/ferrite antenna loading tool, let us apply it to the external dielectric/ferrite loading of a monopole (Fig. 3). A test



	H	W	RESONANT FREQUENCY (MHz)	BW@- 3 dB (MHz)		TEST
				-3 dB	-3 dB	
▬▬▬	12.5"	12"	215	140	≈ 500+	3B-14
▬ ▬ ▬	12.5"	5.8"	215	160	≈ 500+	3A-12
●●●●●	12.5"	1/8" ROD	225	190	290	JK-7
NOT PLOTTED	24"	12"	110	≈ 80	300	3B-24
NOT PLOTTED	24"	5.8"	112	≈ 70	310	JK-11
NOT PLOTTED	24"	1/8" ROD	115	95	140	JK-4

Figure 4 · Antenna gain/bandwidth as a function of width (12", 5.8", 1/8") for a constant height (12.5") antenna.

Figure 5 · Astron model AA-302000 Airborne Blade antenna, operating over 30 to 2000 MHz (readily extended to 2500 MHz), minimum gain of –10 dBi 30 MHz (over 5 dBi higher than available to date) with an average gain of over 0 dBi from 60 to 2000 MHz, 100 watts input power and a minimal VSWR of 2.5:1.

was run, on the Astron VHF/UHF calibrated range to verify the theory regarding the ideal location of dielectrics and ferrites on a monopole antenna to achieve maximum foreshortening. A special jig composed of a hollow 20 inch low RF loss fiberglass cylinder (1 inch O.D.) was devised for holding a 20 inch, 1/8 inch O.D. copper rod at the tube's center in a vertical position. The first test, 89A, involves measuring the copper rod (operating as a monopole) RF response versus frequency with the HP network analyzer set to sweep over the frequency range of 20 to 160 MHz. The 20-inch rod monopole has a maximum response at its resonant frequency of 135 MHz (see Fig. 3). Its efficiency at its resonant frequency should be 100%, and indeed it is, note the 100% efficiency mark at the 132 MHz mark obtained from the range initial calibration.

The next test, 89C, involved filling the lower 5 inch of the fiberglass cylinder jig (still holding the 20-inch rod at its center axis in a vertical position) with a powdered ferrite having a μ of 4. The powder surrounded the rod at its base, externally loading the bottom 5 inches. The maximum foreshortening expected would be the square root of 4, or 2:1. The 1/8 inch copper rod is only partially loaded with ferrite material, and the effect of the ferrite was to lower the resonant frequency to 112 MHz (from 135 MHz). This effectively achieved only a foreshortening of 1.24, the 20-inch rod's electrical length effectively being increased from 20 inches to 24.8 inches.

The next test, 89H, removed the ferrite powder and added 5 inches of dielectric powder ($\varepsilon = 4$) at the top 5 inches of the rod. The result was similar to test 89C, a decrease of the resonance to 112 MHz and an effective foreshortening of 1.24.

The last test, 89P, left the 5 inches of dielectric at the top 5 inches, and returned the 5 inches of ferrite powder at the bottom of the 1/8 inch rod. The resonance dropped to 98 MHz, a foreshortening of about 1.5, and increasing its effective electrical length to 28 inches. In all tests the efficiency was essentially 100%.

These tests showed that the optimum position for the ferrite is at the base (where the current is the highest) while the optimum position for the dielectric is at the top (where the voltage is highest).

Gain and Bandwidth

Data for a constant height antenna (12.5 inches) while varying its width incrementally—12, 5.8, and 1/8 inch— clearly shows the expanding gain/bandwidth (Fig. 4). It was the combining of the above discussed HESA technologies which enabled Astron to achieve the desired JTRS/SINCGARS airborne blade antennas (Fig. 5). Other HESA technologies are available for direction finding arrays, SATCOM and UHF/VHF/UHF communications antennas.

References

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About the Author

Joseph R. Jahoda, Astron's Chief Technology Officer, founded Astron 27 years ago. He graduated from College of the City of New York in 1950 with a B.E.E., and from Polytechnic Institute of Brooklyn in 1954 with a M.E.E. He has been involved in R&D for ECM and Communications Systems ever since.

The Astron Wireless Technology, Inc. Web site is www.astronwireless.com

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Correction to a Novermber 2006 Article

Some errors in units found their way into the article, "Radiated Power and Field Strength from UHF ISM Transmitters," by Larry Burgess, in the November 2006 issue. The character "µ" was inadvertantly dropped from various field strength numbers. Field strength data and specifications presented in the article are in units of µV/meter, not V/meter. The errors occurred on page 18 (first column, near the bottom), and on page 20 (right-hand column, paragraph above the section, "Voltage and Power at the Measurement Receiver").