Spinning Magnets: An Unconventional Method for Compact Generation of ELF Radio Signals

D. P. Arnold*, H. C. Burch, M. F. Mitchell, A. Garraud, and R. C. Moore
Dept. of Electrical and Computer Engineering, University of Florida
Gainesville, FL, USA
*darnold@ufl.edu

***Abstract*— This abstract presents a compact, low-power method for generating extremely low frequency (ELF) radio signals. Rather than relying on conventional techniques, which utilize electrical currents flowing through an antenna, time-varying magnetic fields are generated via the physical rotation of a 3 cm^3 permanent magnet. The resulting electromagnetic signal at ~500 Hz was easily detectable at ground distances approximately 100 m from the source.**

Keywords—ELF; transmitter; signaling; magnet

I. Introduction

ELF signaling has significant applications in communications and scientific research, but is often difficult to achieve due to wavelengths in the hundreds of kilometers, which traditionally require km-scale antennas to transmit efficiently [1]. Additionally, magnetic loop antennas are typically considered to be poor ELF radiators due to their relatively low radiation resistance [1]. A permanent magnet, however, can maintain a magnetic field equivalent to a current of several kiloamperes with no consumed power [2]. Physically rotating the magnet produces a time-varying magnetic field, thereby generating a propagating electromagnetic wave. Currently, efforts are underway to evaluate the efficacy of this technique for generating electromagnetic waves. This paper presents initial field-test results demonstrating the successful generation and detection of time-varying magnetic fields.

II. Experimental Setup

In order to evaluate the viability of this method, a field test was performed using a spinning magnet "transmitter" and a magnetic loop antenna receiver.

A. ELF Source

The transmitter consisted of a diametrically magnetized cylindrical permanent magnet mounted to a steel shaft. The magnet used was a Grade N42 Nd-Fe-B (KJ Magnetics RA2ADIA), with dimensions of 5/8” OD x 1/8” ID x 5/8” length, and a magnetic remanance B_r of 1.3 T. For a total magnet volume of 3 cm^3, this corresponds to an equivalent magnetic dipole moment of 3.1 $A \cdot m^2$. The steel shaft was then inserted into the collet of a Craftsman rotary tool, as shown in Fig. 1. In order to turn the transmitter on, the rotary tool was powered on (from wall outlet via ~200 ft extension cord) and set to rotate the mounted magnet at approximately 30,000 RPM (corresponding to 500 Hz).

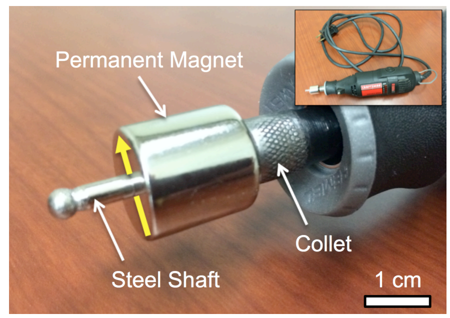

Fig. 1. Closeup picture of the magnet and rotary tool (inset).

B. Receiver

To measure the transmitted wave, a portable ELF receiver was used, as shown in Fig. 2. The receiver has 3 orthogonal 1 Ω–1 mH square loop antennas with a matched low noise amplifier for each channel. All three channels are recorded using a battery-powered Tascam data recorder with a 24-bit analog-to-digital converter and 96 kHz sampling frequency. The complete receiver has a noise floor on the order of 1 fT/√Hz at 1 kHz and a flat frequency response in the range of 300 Hz to 45 kHz.


Fig. 2. Portable 3-axis magnetic field receiver.

Procedure

Measurements were performed on 8 August 2016 at Hume Field on the University of Florida campus; a flat, grassy recreational field away from roads or power lines. The transmitter remained stationary positioned at one corner of the field, while the receiver was moved away at intervals of 10 yards, or approximately 9 m. At each interval, 1 min of data was recorded during which the rotary tool spun up, ran for approximately 30 s, and spun down, so that each data file recorded both isolated background noise and the full transmission. Baseline data sets were also taken at 9 m, with the rotary tool switched off (background) and once with the rotary tool running but no magnet inserted (control) to ensure that the measured signals were not being generated by the tool.

For the primary experiments, the rotating magnet was held by hand approximately 2.5 m above the ground with the axis of rotation vertical. However, a second trial was also run at 37 m with axis of rotation transverse to the line from the transmitter to the receiver. All other aspects of the experiment remained the same for this test.

III. Experimental Results

Observations in spectrogram format are shown in Fig. 3. At each distance, the amplitude of the radial magnetic field B_r was largest, followed by that of the azimuthal field B_φ. In all cases, the amplitude of the vertical field B_z was the lowest, as expected. In each of the figures, the frequency of the field is observed to increase with time initially, settle near ~500 Hz for ~30 s, and then decrease as the rotary tool spun down. Overall, the power spectral density at the steady-state speed (ranged from 490 Hz to 530 Hz) was observed to decrease with $1/d^6$ (meaning field amplitudes decreased with $1/d^3$) where d is the distance from the ELF source. This $1/d^3$ rolloff matches the expected behavior of a magnetic dipole.

IV. Conclusions

Time-varying magnetic fields in the ELF band can be generated by spinning magnets. Further analysis is required to investigate the efficacy of this method for generating propagating electromagnetic waves in this frequency band. Nevertheless, this work demonstrates that communications by signaling at ELF frequencies over distances of ~100 m are possible by changing the orientation of a static magnetic moment with time.

References

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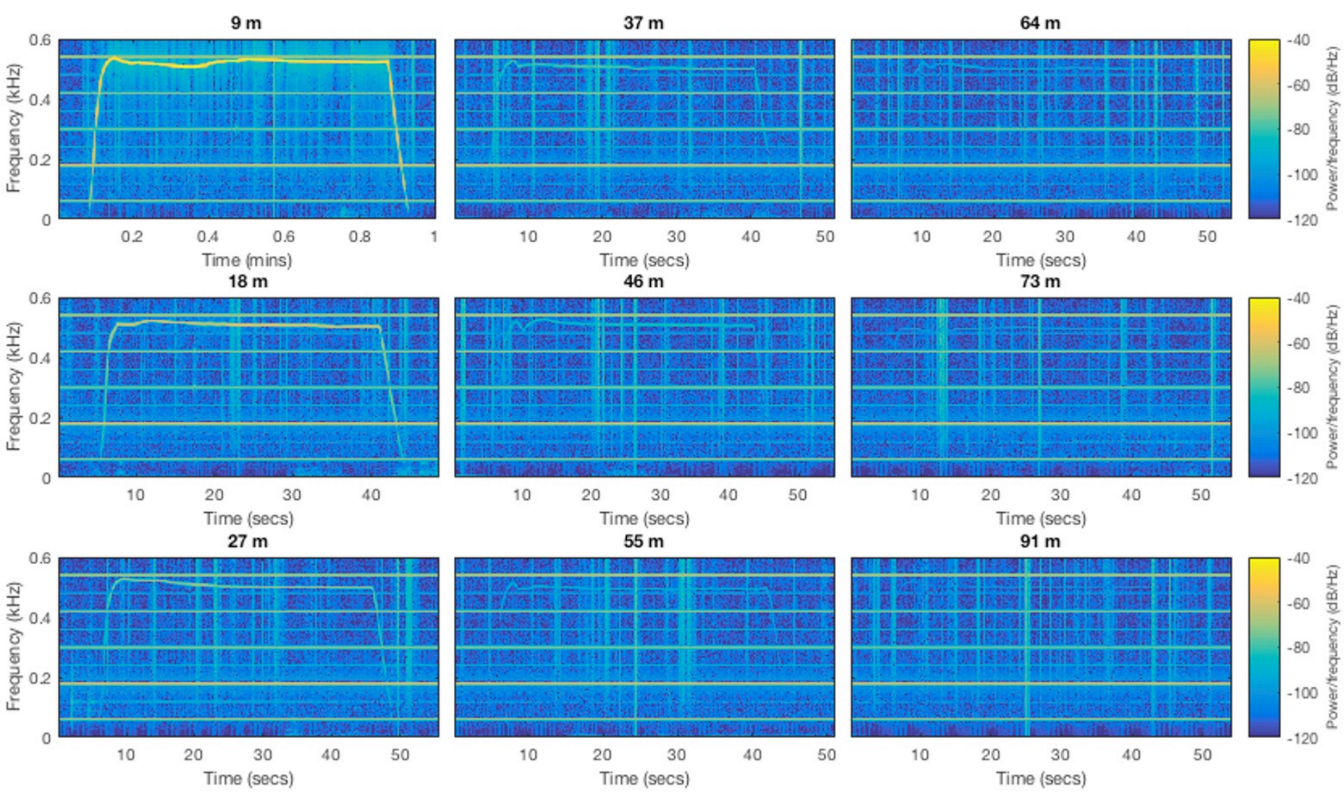

Fig. 3. ELF observations of the radial component of the magnetic field (frequency/time spectrograms) at 9 different distances from the ELF source.